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Lenses and Techniques for Aerial Color

Several factors influence color balance: color correction, spectral transmission and light fall-off of the lens, estimation of haze and its variation with altitude, illumination of the object, selection of filter and film.

INTRODUCTION

COLOR AERIAL PHOTOGRAPHY forces us to pay greater attention to the factors that should be familiar to us from black-and-white photography, but which we have come to disregard—to some extent with good justification. A more profound knowledge of the various influences that may have an adverse effect on the results achieved in color photography constitutes the real difference between the techniques of black-and-white and color photography.

What should be required as the results of a properly executed photographic mission? The requirement should be defined as color photographs whose color composition harmonize substantially with the natural color perception of our visual apparatus, taking into consideration the physiological condition of the observer. According to this definition, a picture with a dominant color bothering our color perception—in other words, with a color cast—cannot be called a good result. Of course, this does not apply to false-color films or to films where special color effects or color differentiations were attempted through the use of color filters. This definition of results must be qualified with the statement that a picture with a color cast is often unavoidable because of atmospheric influences. The information content of such a picture can nevertheless still be better than of one which is black-and-white.

ABSTRACT: *The result of an aerial color photographic mission cannot easily be predicted without a good knowledge of the factors having an influence on the final result. This paper gives a short description of the characteristics of the taking lenses with respect to color photography, as well as information about the influences of the atmosphere, the choice of filters and the determination of correct exposure for different types of aerial color films. Recommendations are given for the choice of film for a given project.*

Such familiarity with these influences and their interrelationship are of twofold importance in color photography: first, in the successful planning and execution of an aerial photographic mission; second, in the assessment of the results obtained and, where necessary, in the taking of the proper corrective steps for subsequent assignments.

It must be said at this early stage that the possibilities of influencing the results are limited; these limitations are based primarily on atmospheric effects. Moreover, it must be considered that the atmospheric conditions are judged visually, thus introducing great difficulties into the entire system of color photography, mainly with regard to the reproducibility of a given result.

In the following, a number of interesting points will be treated that have an influence on the results and must therefore be noted.

AERIAL CAMERAS

Of special interest for color photography are the optical properties of the taking lenses with regard to: (a) chromatic correction; (b)

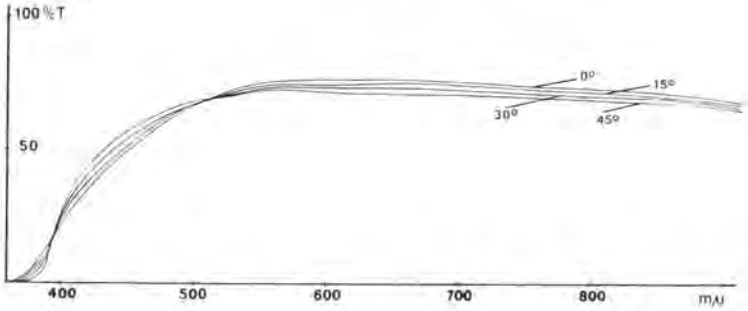

FIG. 1. Spectral transmission of the 6-inch Aviogon and Universal Aviogon lenses.

spectral transmission; and (c) light distribution in the plane of the picture.

CHROMATIC CORRECTION

Aviotar, Aviogon and Super-Aviogon lenses are chromatically corrected for the spectral range from 450 to 650 nm.* The 6-inch Universal Aviogon and the new 3.5-inch Super-Aviogon II of the RC-10 aerial camera are chromatically corrected for the spectral range from 450 to 850 nm. All these lenses are therefore suited for color photography. If films are to be used whose sensitivity range extends into the long-wave region, such as Kodak Ektachrome Infrared Aero Film 8443, the Universal Aviogon and Super-Aviogon II lenses are to be preferred.

SPECTRAL TRANSMISSION

The spectral transmission of the Aviogon or Universal Aviogon lenses and of the Super-Aviogon lens can be seen in Figure 1 and Figure 2. These curves indicate that these lens types—like all high-performance lenses of photogrammetric cameras—have little transmission in the short-wave spectral range. This slight filter effect is of advantage also in color photography because the undesirable short-wave portion of the radiation is thereby eliminated.

LIGHT FALL-OFF

The unavoidable light fall-off of the lens types under discussion is problematic as the physical initial light fall-off, the field angle of the lens, and the atmospheric conditions are interconnected. Consideration should be given to the fact that the atmospheric light scatter counteracts the physical initial light fall-off dependent upon the field angle. In the Aviogon and Super-Aviogon lenses, for example, the light fall-off at $f/8$ corresponds approximately to the cosine of the third power (Figure 3). The often quoted law that the light fall-off follows the fourth power of the cosine is valid only for lenses with a front aperture diaphragm and does not take into account the design characteristics of modern lenses. To compensate the light fall-off, filters with a vacuum-deposited layer of diminishing density from the center towards the edge are placed in front of the lens.

Because color films have little exposure latitude, and partial density differences are easily noticeable, the lightening effect must be taken into account in the selection of the graded-density filter. The atmospheric light scattering directed towards the lens (aerosol) causes the uneven illumination in the plane of the picture depending on the solar altitude and the field angle of the lens. As the amount of light-scatter upwards depends on the volume of "aerosol" between the terrain and the lens, some means must be found to evaluate this atmospheric influence. It is understandable that under equal atmospheric conditions the lightening effect at, say, 1,000 meters is less than at, say, 4,000 meters, and that a graded-density filter which is correct for 1,000 meters flying height is too dense for a flying

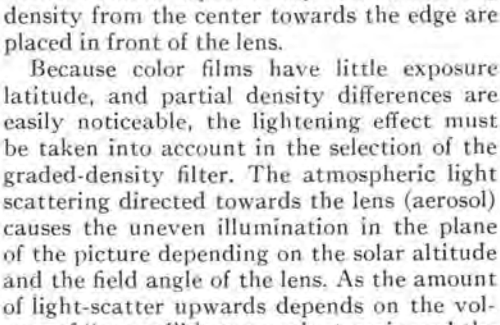

FIG. 2. Spectral transmission of the 88-mm. Super Aviogon lens.

* Nm = nonometer = 10^{-9} meter.

height of 4,000 meters. The result of this example would be that the photographs taken from a height of 4,000 meters would suffer from noticeable under-exposure in the center of the picture.

A possibility to determine the maximum density of the graded density layer in practice has been shown by Duntley[3]. An optical standard atmospheric is a prerequisite there, and the maximum density of the graded density layer is obtained as a function of horizontal visibility and flying height.

In connection with the graded density layer, the spectral composition of the scattered light and its registering on the film are of consequence. The "aerosol" particles are selective in their spectral dispersion, depending on their size. It can be said that the shortwave portion of the scattered light grows in direct proportion with the visual range. In this simplified explanation, the spectral composition of the scattered light that depends on the solar altitude is not taken into consideration. Assuming that in practice color photographs are taken under meteorological conditions where horizontal visibility exceeds 50 kilometers and the solar altitude ranges from 40° to 50°, then the blue portion in the scattered light will be approximately three times greater than the red portion. As mentioned earlier, it is the upwards-directed portion of this scattered light that is responsible for the additional illumination (lightening) in the plane of the picture. Because conventional color films also register the blue range of the spectrum, whereas in false-color films the blue is cut off by means of a Wratten No. 12 filter (500 nm), it is understandable that a graded-density filter with a 2.2× anti-vignetting coating yields a more satisfactory compensation over a greater range of flying heights with false-color film than with conventional color film.

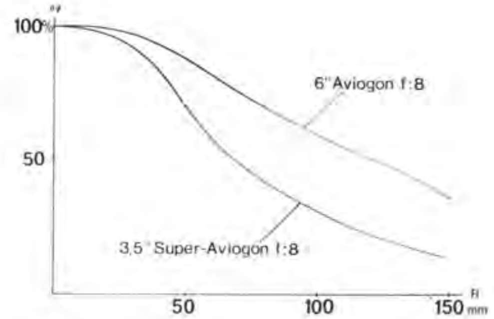

FIG. 3. Relative illumination in the negative plane.

DETERMINATION OF EXPOSURE

The Kodak Aerial Exposure Computer usually gives good results for color photography, provided that the atmospheric conditions are properly evaluated. The figures given for the speed of Kodak color films are merely index figures for use in combination with Kodak Aerial Exposure Computer. Should an exposure meter be used, the Aerial Exposure Computer can be useful to determine the USASI rating of a certain type of film. In using an exposure meter one should be aware that there must be compatibility between the spectral sensitivity of the respective film emulsion and the meter measuring cell.

Figure 4 shows that the difference in spectral sensitivity between cadmium sulfide cells and selenium cells is considerable. A comparison of the spectral sensitivity characteristics of the meter cells and of the color film indicates that selenium cells—as used for instance in the Weston Master exposure me-

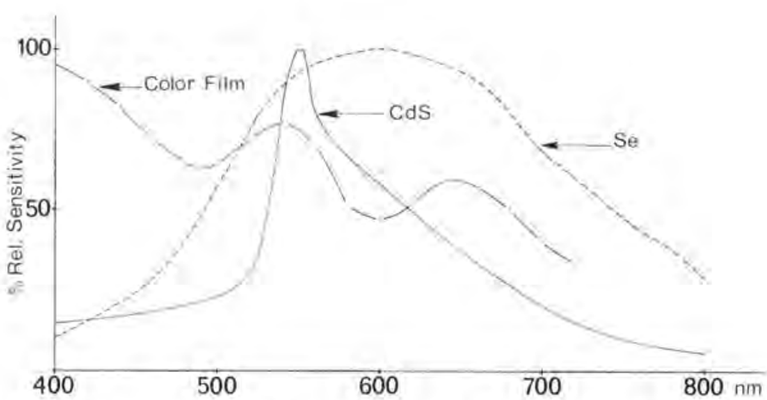

FIG. 4. Relative sensitivity of the cadmium-sulfide and selenium cells and color film.

ter—are better suited than CdS cells. The CdS cells, however, have a much greater total sensitivity: it is therefore possible to place a filter combination before the meter cell to reduce the greater sensitivity peak between 525 and 580 nm. This results in a more even spectral sensitivity over a wider range. The USASI value must of course be adjusted in accordance with the density of the filters used.

It is interesting to note that these cells (CdS) have a relatively low sensitivity between the range of 400 and 500 nm, which is the range where normally scattered light is most intensive under normal conditions.

As mentioned previously, the composition of the atmosphere, the sun angle and the flying height all contribute extensively to the amount of scattered light. For this reason, it is suggested that the USASI rating of normal color film be increased with the flying height. Experience has shown that it is best to base the USASI rating on a 1,000 meter flying height and to increase it by 30 percent for each additional 1,000 meters.*

Atmospheric and Filter

The question of choice of proper filter in front of the taking lens arises if a normal color film such as Kodak 2448 is to be developed as a positive transparency. In this instance the best possible color balance is required to utilize the inherent color distribution of the film.

Color films are sensitized for a mean daylight of 5,400°K. In aerial photography, however, the composition of daylight changes depending on atmospheric conditions and the sun angle. Three factors must be taken into consideration to compensate for this:

- What is the spectral composition of the rays falling on the subject?
- What is the amount of spectral reflectance of the subject:
- What influences affect the rays between the objective and the subject?

It is known that the subject or terrain is illuminated by a mixture of sunlight and skylight. The skylight is scattered by particles in the atmosphere (aerosol). On a clear day at a horizontal visibility of 100 kilometers and 40° solar altitude the ratio of sunlight is four to one, this rapidly changes to three to one at 40 kilometers visibility. At the same time, the spectral composition of the entire illumination changes. A decreasing solar altitude will also change the spectral composition of the entire illumination. In short, the proportion of the predominately red (direct sunlight) and blue (skylight) changes continuously. For the sake of simplicity, let us ignore the influence of the spectral reflectance effect (the second factor) on the subject. There remains the influence of the haze layer between the subject and the lens which, depending on its thickness (flying height) and density (particle size) superimposes principally short-wave light on the image-forming rays. In addition, the spectral composition of the image-forming rays changes with the atmospheric influence (haze) and depends on the angular field of the objective.

This short analysis of the complex conditions of illumination encountered in aerial photography shows that we must be rather tolerant with respect to the color balance we can expect in the picture and that we cannot expect wonders from the use of filters during the picture taking, especially at high altitudes. In practice, the only remaining possibility of reducing the increasing amount of short-wave encountered with greater flying heights is through the use of light yellow filters (CC 05, CC 10, CC 15) (See Determination of Exposure above).

Choice of Film

From the problems listed previously, one can understand that the reversal process is beset with numerous problems during the picture-taking stage. It is recommended extensively where film diapositives are to be used directly for photogrammetric compilation.

Wider possibilities are offered, however, through the use of reversal film developed and processed to the negative, such as Kodak 8442 or 2448. Compared with Ektacolor negative film, it has the advantage that it is higher in contrast and therefore more suitable for flying at higher altitudes. Experiments with Ektacolor film have shown that the maximum flying height with respect to color contrast is around 1,500 to 2,000 meters. The development to the negative has many advantages, such as skipping color balance filtering of the picture. The color balance is adjusted in the dark-room following the copying process. Color copies and enlargements are

* The Reviewer understands this to mean if the USASI is 100 at 1,000 meters, it becomes USASI 130; at 2,000 meters, a USASI of 160; at 3,000 meters, a USASI of 190; at 4,000 meters and at 5,000 meters, a USASI of 220. The Reviewer also believes that this formula is not intended to be carried through to infinity and that the probable cutoff point is around 5,000 meters of flight altitude.—*Reviewer's comment.*

easy to produce. The Wild VG-1 Enlarger and E-4 Rectifier can now be delivered with a color head for the additive filter process. Existing instruments can be retrofitted. This accessory is easily exchangeable with the standard lamp housing.

Black-and-white prints and enlargements can either be produced on standard bromide or panalure paper. Prints made on panalure paper have a somewhat extended tonal contrast over comparable prints made on normal bromide paper.

With reference to Kodak color films developed to the negative, one has the choice between Ektachrome Aero Film 8442 and Ektachrome MS Aerographic Film 2448. Both types of film can be developed in the normal or modified C-22 process. (Kodak recommends only type 2448 and the modified C-22 process.) The advantages of 8442 films are: four times higher speed (Aerial Exposure Index 25, approximately ASA 125); and somewhat harder gradation of the emulsion, therefore more suitable for higher altitudes. The advantages of the 2448 compared to the 8442 are: Estar base, 35 percent higher resolution measured at 1,000:1 and 43 percent at 1.6:1. The somewhat lower speed of the 2448 (Aerial Exposure Index 6, approximately USASI 30) is still sufficient for most practical flying conditions. In addition, one can lengthen the first development time by approximately 30 percent and gain about one stop without noticeably losing quality. The gradation does not increase with longer developing time; that is to say, with color one cannot partially compensate for loss in contrast due to high altitude through longer developing as is the case with black-and-white film.

For flying from low to medium altitudes, the 2448 has more advantages than the 8442; the latter should be given preference for higher altitudes.

Ektachrome Infrared Aero Film 8443 (False Color Film) holds a unique position among the color films. The *original* colors of the terrain are reproduced falsely on this reversal color film. If the original radiation (with the 500 nm. filter) was, for instance, blue, it will be registered as black, green as blue, red as green, green and infrared as magenta and infrared as red.

From the above remarks it becomes evident that this film is especially suited for forestry, agriculture, resources and irrigation purposes. Technically, the film is easy to handle because the 500 nm. filter eliminates the atmospheric influences to a large extent. A certain disadvantage is that processing to a negative in the C-22 process produces unacceptable results. The contrast of the cyan layer (the layer which is infrared sensitive) becomes very flat due to reduced differentiation. The film is suitable for use with other filters or filter combinations, in addition to the 500 nm. filter for studies of specific terrain features.

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